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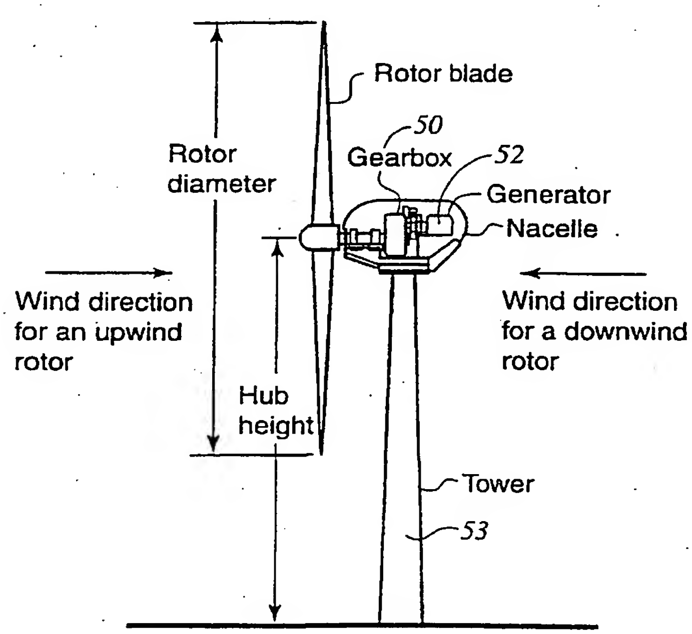
(54) **Title:** PLANETARY GEAR STAGE



(57) **Abstract:** A gear unit comprises a planetary stage having at least one bearing which locates a planet carrier rotatably relative to a ring gear, wherein a bearing ring (A) is subject to local deformation as the planet carrier rotates relative to the ring gear, and wherein a bearing ring (B), which is rotatable synchronously with the planet carrier, is precompensated whereby, in comparison with a non-precompensated bearing ring (B), radial squeezing of the rolling members of bearing or load concentrations or local unloading of the rolling members of the bearing is reduced.

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PLANETARY GEAR STAGE

The need for weight reduction in mechanical drives has in the past lead to an increased use of planetary gear units.

In a number of applications, more and more integration and lightweight designs are being introduced. This leads to a higher importance of deflections and local deformations. This applies particularly in the case of a gear unit for use in a wind turbine and for which application it has been proposed optionally to utilise a ring gear to act as a support directly for an inner or outer bearing ring.

This invention addresses the consequence on bearing performance of local deformation of the ring gear of a planetary gear stage by the passage of the planets in the relative motion of the gear system.

As shown diagrammatically in Figure 1, the resultant gear force (Fn) acting at the gear contact between a planet gear 10 and ring gear 11 includes a radial (Fr) and a tangential (Ft) component. Also axial forces may occur for instance when helical gears 10 are used.

Although the present invention seeks to consider all components of the occurring forces, it is to be understood that for instance the radial force can lead to significant local elastic deformations of the ring gear. When the gear unit is in operation this deformation will run through the ring gear at a speed which is synchronous with the moving planets i.e. with the planet carrier 12.

The magnitude of this deformation will depend on the forces and the surrounding structural stiffnesses.

In typical state-of-the-art planetary gear units, the planet carrier 20 (see Figure 2) is mounted in bearings 21 which center in the ring gear 22 via an intermediate flange or housing 23.

This means that any local deformations of the ring gear due to the passage of the planets will be distributed more evenly by this intermediate flange or housing. Thus when load is applied to the bearings, for instance external forces from the rotors of a wind turbine, they will be operating with loads that are relatively well distributed over the different rollers of the bearings.

Figures 3a to d show examples of a more integrated and lightweight design, where the application, such as a wind turbine rotor, can be directly, or via a flange, connected to the planet carrier (Figure 3a, 3b, 3c) or to the ring gear (Figure 3d). Also external forces which may come from the connected application will have to be supported by the construction.

Because of the integration, the structural stiffnesses of the system change and forces acting in the gear contact between planets and ring gear can now lead to significant local deflections of the bearing(s)

- in Figure 3a, 3c and 3d, the outer ring 30 of the bearing(s) will deform locally at the passage of the planets 31.
- in Figure 3b, a variant of Figure 3a, the inner ring 32 of the bearing will deform locally at the passage of the planets 34.

As can be seen from the examples in Figure 3, it is always the bearing ring connected to or integrated with the ring gear 35 which suffers from the above type of local deformation. By definition herein, we call this bearing ring A, whereas the other bearing ring which rotates synchronously (including standing still) with the planet carrier is called bearing ring B.

The present invention seeks to provide a gear unit comprising a planetary stage in which the aforedescribed difficulties are mitigated or overcome.

In accordance with one aspect of the present invention a gear unit comprises a planetary stage having at least one bearing which locates a planet carrier rotatably relative to a ring gear, wherein a bearing ring A of said bearing is subject to local deformation as the planet carrier rotates relative to the ring gear, and wherein said bearing comprises a bearing ring B, which is rotatable synchronously with the planet carrier, is precompensated whereby, in comparison with a non-precompensated bearing ring B, radial squeezing of the rolling members of bearing or load concentration or local unloading of the rolling members of the bearing is reduced.

The present invention thus provides a bearing ring B construction which compensates for the local changes in geometry of bearing ring A. As bearing ring B rotates (or stands (as in Figure 3d) synchronously with the planet carrier, the deformation waves caused by the planets will rotate

synchronously with the precompensated bearing ring B construction. Therefore the precompensation works in all rotational positions of the gear system.

Reference is now made to the cross-sectional view in Figure 4 (which is a cross-sectional view of Figure 3b), and Appendix A which is a key to Figure 4, to describe, by way of example only, one embodiment of the invention. This is described in relation to the aforementioned construction of Figure 3b. If the precompensating construction is not employed, the rolling elements 6 of the bearing would be squeezed between the deformed outer contour 6 of the ring gear 3 and contour (c) of the bearing outer ring 5. The construction with precompensation results in a contour (d) of the bearing outer ring 5, thus avoiding undesirable squeezing of the rolling elements 6 and resulting in a better distribution of loads applied to the bearing.

This leads to advantages such as lower weight of the ring gear 5 because of reduced required stiffness and selection of smaller or lower cost type bearing(s). Also the overall structural stiffness can be controlled better, which results in the potential for improved dynamic behaviour of the total application system.

The invention envisages accordingly a planetary gear stage with at least one bearing locating the planet carrier relative to the ring gear and where bearing ring A, which can be the inner or the outer ring of the said bearing(s), is deformed locally due to the effect of planet passage in the ring gear, whereby the bearing ring B, rotating synchronously with the planet carrier (including standing still), is precompensated such that squeezing of the rolling elements or load concentrations or local unloading (as would be the case in Figures 3a, 3c and 3d) caused by the local deformation of bearing ring A is avoided.

Options for achieving precompensations include:-

- precompensation by adapting the race geometry of bearing ring B.
- precompensation by adapting the outer surface geometry of bearing ring B.
- precompensation by adapting the supporting geometry for instance by a centering spigot of bearing ring B.

- precompensation by adapting the supporting structure of bearing ring B by providing the supporting structure with a stiffness that enables the supporting structure to compensate elastically for the planet movements
- precompensation by adapting the supporting structure on or in which bearing ring B is located with preload.

The adaptation to achieve precompensation is preferably effected by selective dimensioning, for example to make component dimensions larger or smaller than normal. The selective dimensioning may achieve precompensation by resulting in either elastic or geometric compensation.

A gear unit 50 of the present invention is particularly suitable for use in a wind turbine (see Figure 5) to transmit torque between the rotors 51 and an electrical generator 52 mounted at the top of a tower 53.

APPENDIX A

Key to Figure 4

1. Sun pinion gear
2. Planet gear
3. Ring gear
4. Planet carrier
5. Outer bearing ring (Rotates synchronously with planet carrier – see Figure 3b)
6. Bearing rolling system

a. Non-deformed outer contour of ring gear
b. Deformed outer contour of ring gear
c. Inner contour of outer bearing ring without precompensated construction
d. Inner contour of outer bearing ring with precompensated construction
e. Offset zone of inner contour of outer bearing ring

n_1 Rotational speed of planet carrier

n_2 Rotational speed of outer ring of bearing

CLAIMS

1. A gear unit comprising a planetary stage having at least one bearing construction which locates a planet carrier rotatably relative to a ring gear, wherein a bearing ring A of said bearing construction is subject to local deformation as the planet carrier rotates relative to the ring gear, and wherein said bearing construction comprises a bearing ring B, which is rotatable synchronously with the planet carrier, is precompensated whereby, in comparison with a non-precompensated bearing ring B, radial squeezing of the rolling members of the bearing or load concentrations or local unloading of the rolling members of the bearing is reduced.

2. A gear unit according to claim 1 wherein precompensation is achieved by adaptation of the race geometry of bearing B.

3. A gear unit according to claim 1 wherein precompensation is achieved by adaptation of the outer surface geometry of bearing ring B.

4. A gear unit according to claim 2 wherein said bearing ring B comprises a non-cylindrical surface for contact by bearing rolling elements.

5. A gear unit according to claim 4 wherein said bearing surface comprises a number of surface zones of cylindrical shape alternating with a number of circumferentially spaced zones which lie offset radially from said cylindrical surface, the number of said zones being equal to the number of planet gear positions.

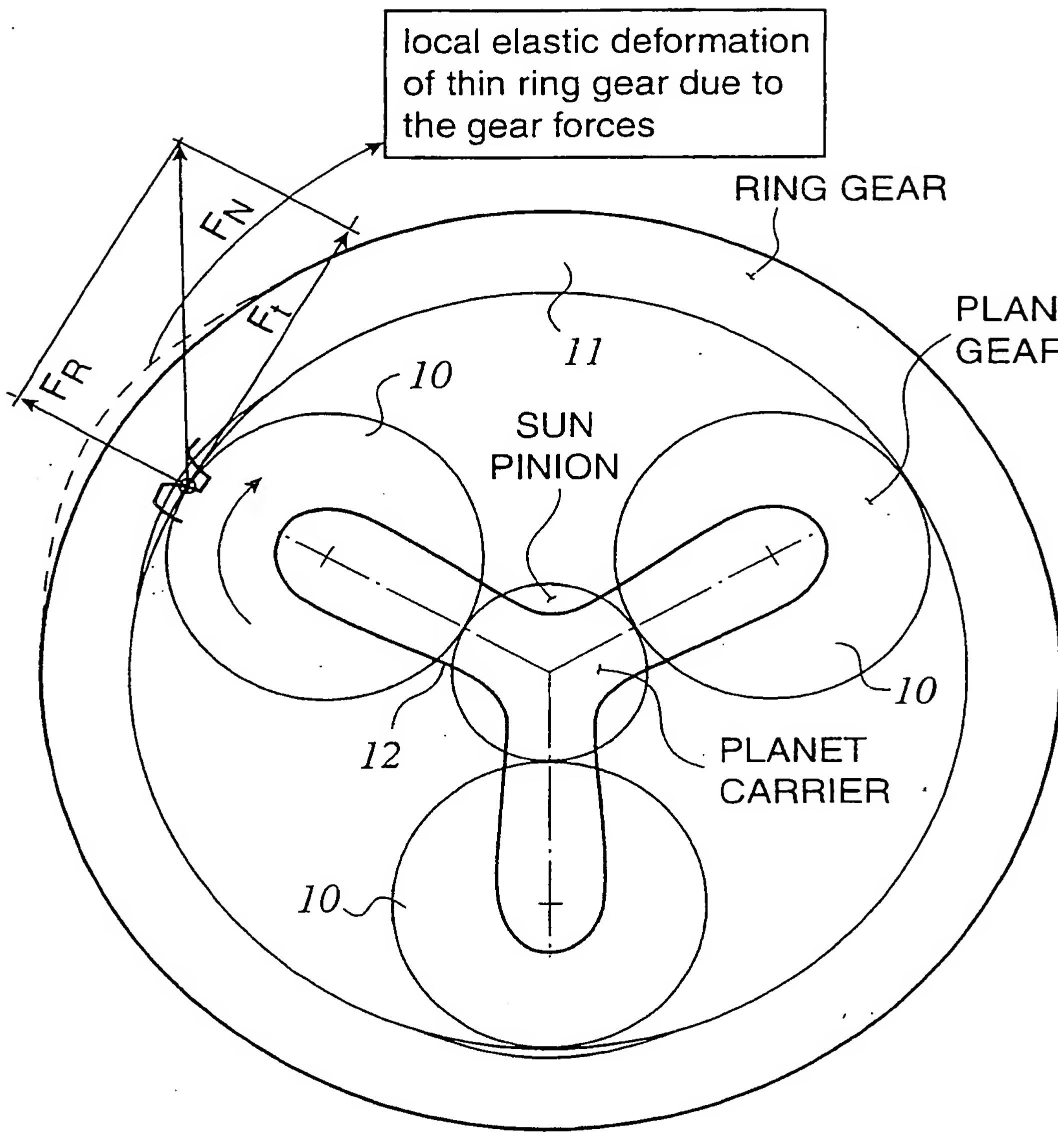
6. A gear unit according to claim 1 wherein precompensation is achieved by adaptation of the supporting geometry.

7. A gear unit according to claim 1 wherein precompensation is achieved by providing the supporting structure with a stiffness in consequence of which said supporting structure is enabled to compensate elastically for deformation of the bearing ring B during movement of the planet gears.

8. A gear unit according to anyone of the preceding claims wherein precompensation is achieved at least in part by selective pre-load of a supporting structure on or in which the bearing ring B is located.

9. A gear unit substantially as hereinbefore described with reference to Figure 4.

10. A wind turbine gear transmission assembly comprising a gear unit according to any one of the preceding claims.



PLANETARY GEAR STAGE
(1 TOOTH PAIR SHOWN ONLY)

FIG. 1

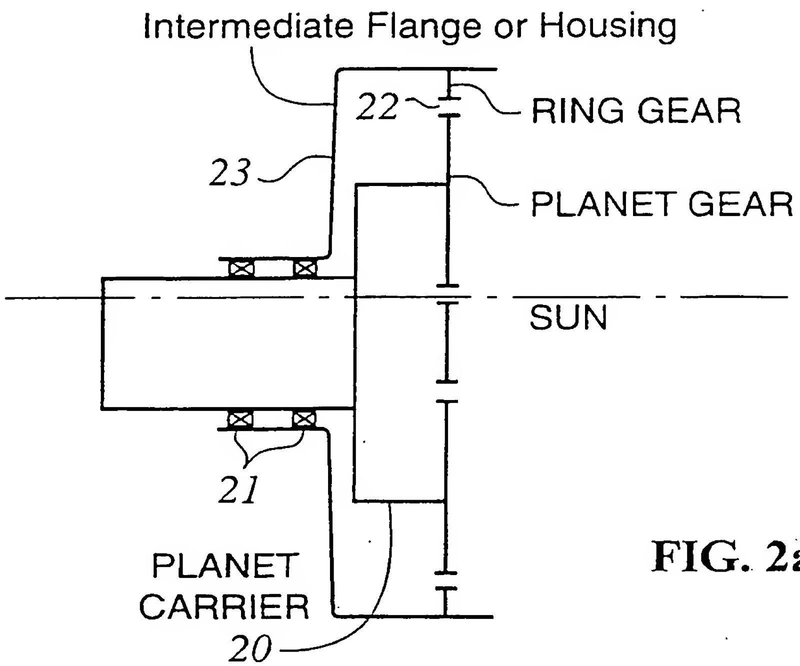

Intermediate Flange or Housing
22
RING GEAR
23
PLANET GEAR
SUN
21
PLANET
CARRIER
20

FIG. 2a

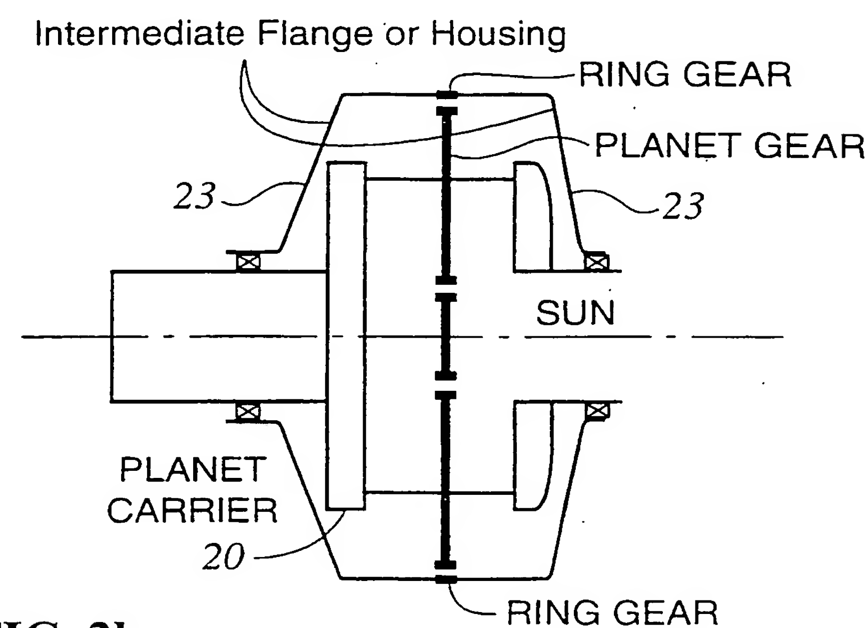

Intermediate Flange or Housing
RING GEAR
PLANET GEAR
23
23
SUN
PLANET
CARRIER
20
RING GEAR

FIG. 2b

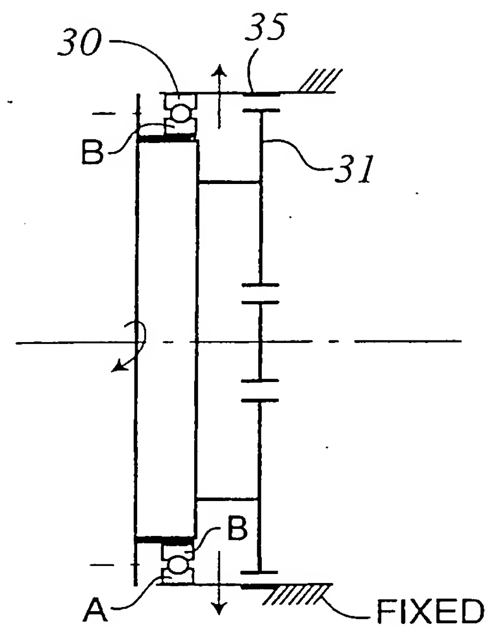


FIG. 3a

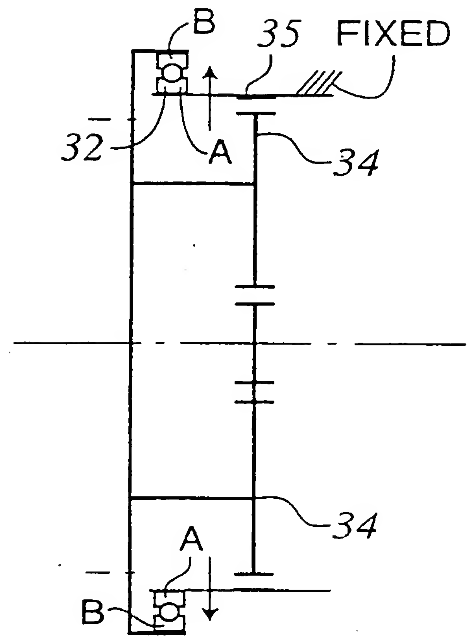


FIG. 3b

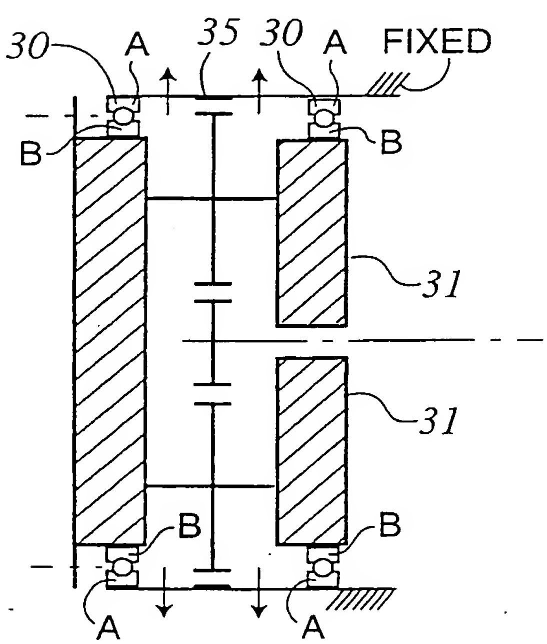


FIG. 3c

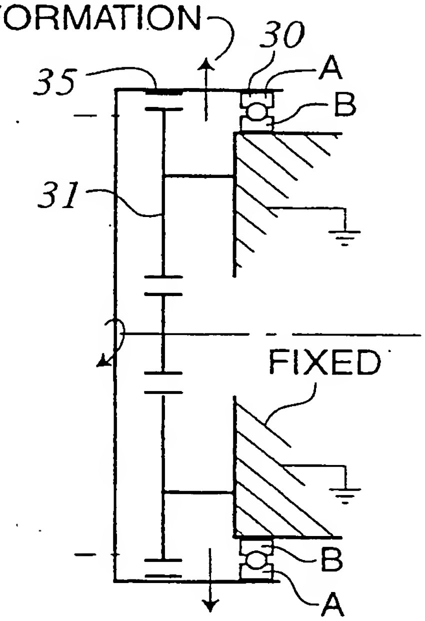


FIG. 3d

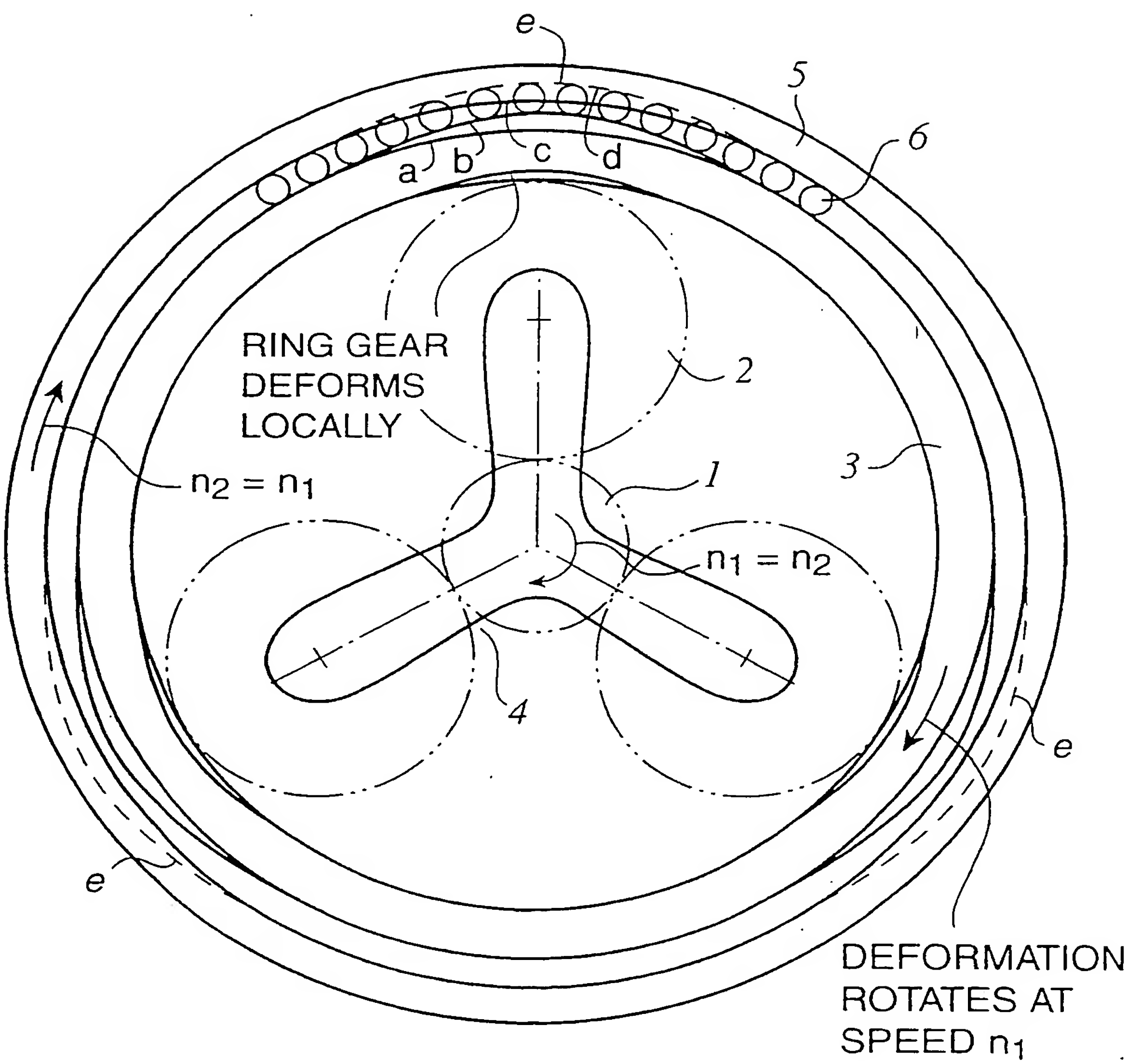


FIG. 4
(Cross sectional view of Fig. 3b)

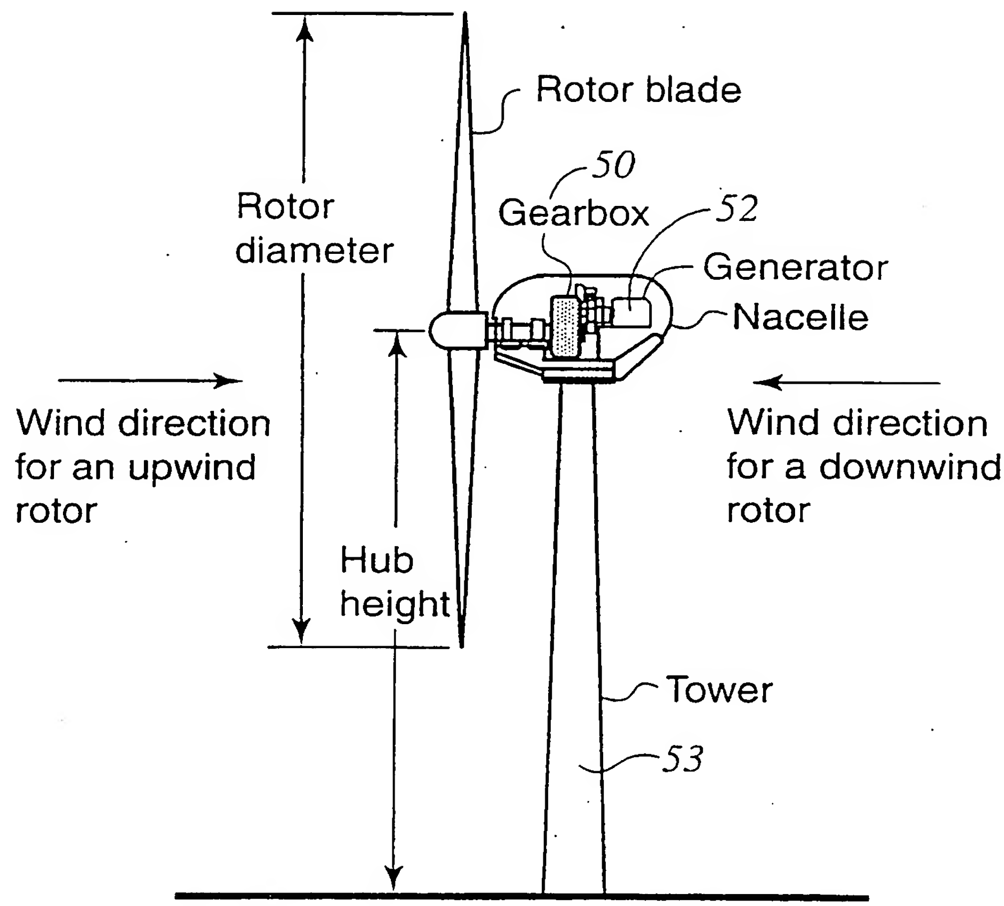

Rotor blade
50
Gearbox
52
Generator
Nacelle
Rotor diameter
Wind direction for an upwind rotor
Wind direction for a downwind rotor
Hub height
Tower
53

FIG. 5